Current ESTO Microwave Investments

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ESTO

Observational Technology Development

- **ESTO has funded instrument and measurement concept development since 1998 through five NASA Research Announcements (NRAs).**
  - **Open, competitive, peer-reviewed solicitations**
  - **Components and instrument subsystems and systems**
  - **Evaluations based on relevance to the Earth Science Enterprise, technical innovation and feasibility, and management factors**
- **During development of each NRA, the solicitation's focus areas are determined based on science needs and technology gaps using the latest available information.**

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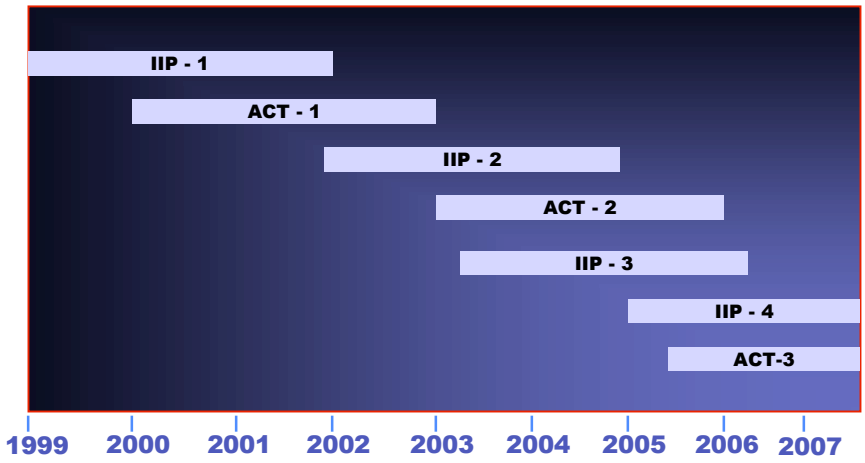
Solicitations with Microwave Content



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Focus for Technology Solicitations

NRA Solicitations	Focus
NMP EO-1 (Space Validation) '96 $192M	Validate technologies contributing to the cost reduction and increased capabilities for future land imaging missions. (Landsat data)
IIP Round 1 (Instruments) '98 27 for $39M	Open and unconstrained; covering active and passive optical and active and passive microwave instruments
NMP EO-3 (Space Validation) '98 $105M	Validate technologies contributing to the cost reduction and increased capabilities for future weather forecasting (future GOES)
ATI Component Technology (ACT Round 1) '99 23 for $17M	Core instrument technology; covering active and passive optical, and active and passive microwave instrument components
AIST Round 1 (Info Systems) '99 30 for $26M	On-board space-based information systems applications including data processing, organization, analysis, storage, and transmission; intelligent sensor and platform control; and network configuration
IIP Round 2 (Instruments) '01 11 for $30M	Microwave radiometry, radar, laser/lidar instruments
ACT Round 2 (Components) '02 14 for $15M	Antenna, electronics, detectors, and optics components
IIP Round 3 (Instruments) '02 9 for $22M	Topo & surface change, Gravity field measurements, sea ice thickness, snow cover, GEO (trop profiles, atm-temp-moisture and rainfall, coastal region), L1 or L2 innovation
AIST Round 2 (Info Systems) '02 21 for $23M	Space/Ground-based, Computational Technology

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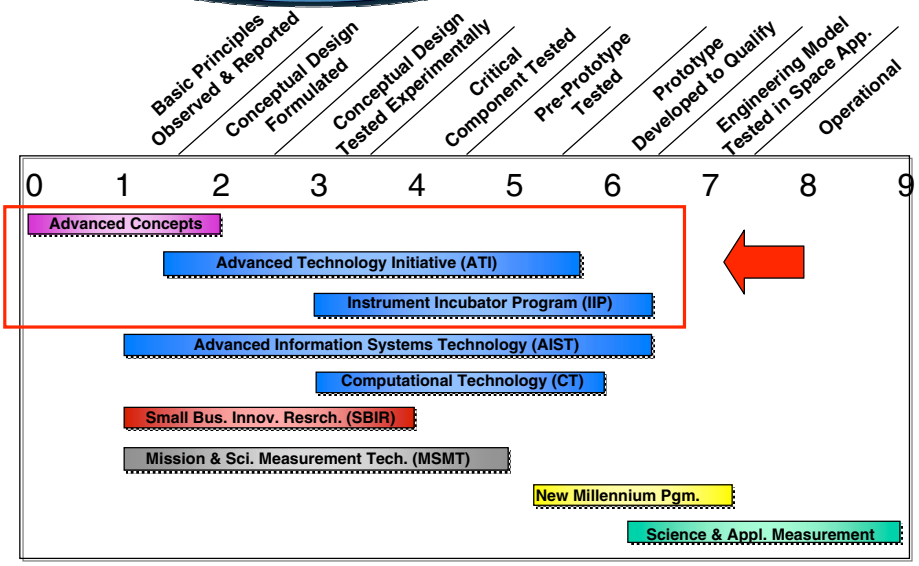
Technology Program Readiness Levels



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Past Investments

- ESTO has selected numerous microwave remote sensing proposals under observational technology NRAs:
  - Instrument Incubator Program (IIP-1, 1998)
    - Radar altimeters; limb sounders; precipitation radar; sounding and imaging radiometers, submillimeter radiometer
  - Advanced Technology Initiatives Program (ATIP, 1999 aka ACT-1)
    - Terahertz limb sounder; Ka-band active feed array; SAR on-board processor; radiometer calibration system, low-power digital correlator, and low-power receiver
  - Instrument Incubator Program (IIP-2, 2001)
    - Advanced precipitation radar antenna, radiometer with interference suppression, dual low-frequency soil moisture radar, lightweight rainfall radiometer, ultra-stable salinity radiometer
  - Advanced Component Technology (ACT-2, 2002)
    - Reconfigurable SAR, SAR transmit/receive modules, microstrip antenna arrays, microstrip antenna feeds, radiofrequency A/D converter
  - Instrument Incubator Program (IIP-3, 2002)
    - Airborne Interferometric SAR, multi-static SAR, GEO precipitation radar, snow/ice radar, GEO sounding radiometer

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Measurements with Microwave Technique

Weather

19

- Atmospheric Temperature and Water Vapor
- Cloud Particle Properties*
- Cloud System Structure*
- Global Precipitation
- Storm Cell Properties

Climate Variability

25

- Ocean Surface Currents
- Ocean Surface Winds
- Ocean Surface Topography
- Sea Surface Salinity
- Sea Ice Thickness & Extent
- Ice Surface Topography*

Water & Energy Cycle

20

- Snow Cover
- Snow Water Equivalent
- Freeze-Thaw Transition
- Global Precipitation
- River Stage Height/Discharge
- Soil Moisture

Earth Surface & Interior

6

- Land Surface Topography*
- Surface Deformation
- Terrestrial Reference Frame (VLBI)

Atmospheric Composition

4

- Atmospheric Temperature and Water Vapor
- Cloud Particle Properties*
- Cloud System Structure*

Carbon Cycle & Ecosystems

6

- Biomass *
- Vegetation Canopy*

*Radar Complementary

Defined Measurement Threshold and Goal Requirements

http://esto.nasa.gov/estips

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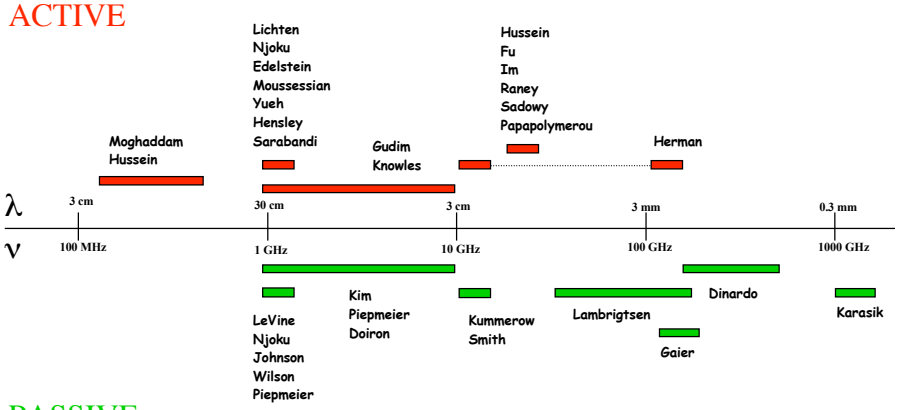
RF Spectrum

Investments cover a broad range of frequencies.

ACTIVE



PASSIVE

VHF	UHF	L band	S band	C band	X band	K_u/K/K_a band	Millimeter	Submillimeter

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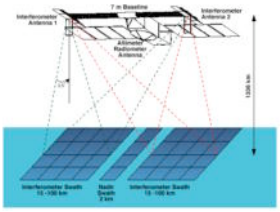
Round 1 IIP Microwave Projects

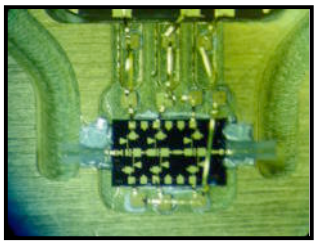
Fu, Lee-Lueng, Jet Propulsion Laboratory
Advanced Altimeter for Ocean Studies
Objective

- Design next generation ocean altimeter which integrates altimeter/radiometer/GPS into one instrument and reduces mass, power, and volume
- Provide significant increase in science:
  - Global measurement of 2-D surface currents
  - Full global sampling of ocean mesoscale eddies, which have the largest contribution to ocean kinetic energy spectrum



Gaier, Todd, Jet Propulsion Laboratory
Millimeter-Wave MMIC Atmospheric Temperature and Humidity Sensors
Objective

- Develop compact, low cost radiometric sensors for the 100-140 and 170-210 GHz bands using monolithic microwave integrated circuit (MMIC) technology.
- The substantial (order of 100) reduction of volume and mass enables arrays of sensors with much greater capability than single-beam sensors.



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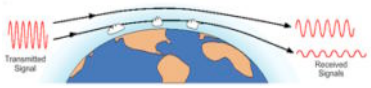
Round 1 IIP Microwave Projects

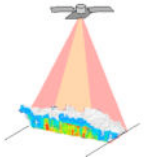
Herman, Benjamin. M, University of Arizona
Active Tropospheric Ozone and Moisture Sounder
Objective

- ATOMS, an atmospheric remote sensing instrument, employs microwave crosslinks at frequencies between 10 and 200 GHz between pairs of low-orbiting spacecraft to perform active atmospheric limb sounding.
- Measure concentrations of ozone and water vapor.
- Provides efficient new window on atmospheric chemistry and climate.



Im, Eastwood, Jet Propulsion Laboratory
A Second Generation Spaceborne Precipitation Radar
Objective

- Design a dual-frequency, dual polarization, Doppler precipitation radar for space applications.
- Improve rain vertical structure measurement, hydrometeor discrimination, swath coverage.
- Reduce mass by a factor of 2-3x from the current state of practice.
- Construct and fly an aircraft instrument.



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Round 1 IIP Microwave Projects

Kummerow, Christian, NASA GSFC

A Small Lightweight Radiometer to Improve the Temporal Sampling of Rainfall

Objective

- Develop a microwave radiometer that is small enough, light enough, and cheap enough to allow multiple copies to be flown in order to overcome the current serious rainfall sampling limitations
- Combine scanning mirror and thinned array channels to allow accommodation on a small bus

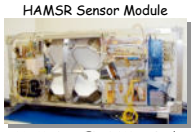
Lambrigtsen,Bjorn, Jet Propulsion Laboratory

High Altitude MMIC Sounding Radiometer (HAMSR) on a Remotely-Piloted Aircraft

Objective

- Design a multifunction sounder for temperature, water vapor, cloud liquid water, and rain in a single package.
- Reduce size, power, and mass and improve performance.
- Build and test an airborne instrument.

HAMSR Sensor Module



HAMSR in ER-2 Wing Pod

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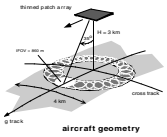
Round 1 IIP Microwave Projects

LeVine, David, NASA GSFC

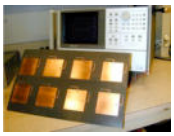
Two Dimensional Synthetic Aperture Radiometer for Microwave Remote Sensing from Space

Objective

- Develop a prototype aircraft passive microwave instrument employing aperture synthesis in two dimensions
- Demonstrate viable S/N, calibration, conical scan, and polarimetric operation



aircraft geometry



Zuffada, Cinzia, Jet Propulsion Laboratory

GOALS: GPS-Based Oceanographic and Atmospheric Low-Earth Orbiting Sensor

Objective

- Assess the science utility of the GPS signal reflected off the ocean for sea-surface topography and develop receiver for on-board tracking and processing

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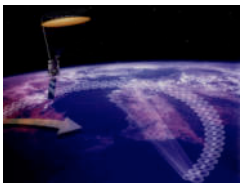
Round 1 IIP Microwave Projects

Njoku, Eni, Jet Propulsion Laboratory
Study of a Spaceborne Microwave Instrument for High Resolution Remote Sensing of the Earth Surface Using a Large Aperture Mesh Antenna

Objective

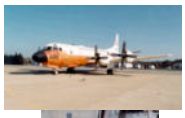
- Develop a system concept for a space instrument that will provide accurate global measurement of ocean salinity and soil moisture.
- Incorporate in the concept a large rotating mesh antenna to measure microwave emission and backscatter.



Raney, Keith, JHU Applied Physics Laboratory
Delay Doppler Phase (D2P) Radar Altimeter

Objective

- Demonstrate, through airborne field tests, the viability and desirability of an innovative altimeter using the delay/Doppler technique to enhance along-track resolution, precision, and power requirements and the phase monopulse technique to mitigate cross-track slope errors
- Demonstrate use over open ocean and ice sheets



Equipment Rack (above)
Antenna Mounting (right)

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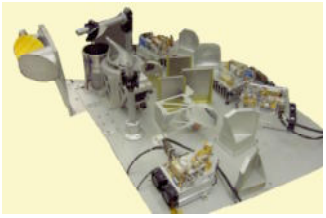
Round 1 IIP Microwave Projects

Dinardo, Steve, Jet Propulsion Laboratory
Submillimeter-Wave Cloud-Ice Radiometer (SWICR)

Objective

- Advance the submm cloud sensing technique maturity to the level needed to enable global characterization of cirrus.
- Design and fabricate an airborne radiometer covering the 183 to 648 GHz frequency range.
- Prepare the system for an aircraft flight.



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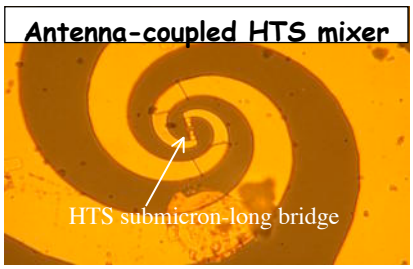
Round 1 ACT Microwave Projects

Karasik, Boris, Jet Propulsion Laboratory

Small and Smart Sensor for Atmospheric Terahertz Limb Sounding

Objective

- Development of a hot-electron heterodyne mixer based on the high transition temperature superconductor (HTS) $YBa_2Cu_3O_{7-d}$, for application to atmospheric high-resolution spectroscopy observations
- This technology would enable a tunable, broadband THz instrument to meet the needs of stratospheric chemistry measurements



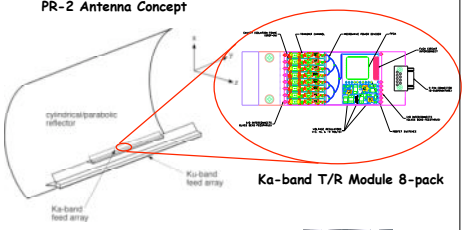
Sadowy, Gregory, Jet Propulsion Laboratory

A Ka-band Active Array for Remote Sensing of Precipitation

Objective

- To develop a dual-polarized electronically-scanned Ka-band (35 GHz) subarray for the PR-2 antenna.
- Development of this subarray will provide a proof-of-concept as well as a design that can easily be adapted for a future flight program.

PR-2 Antenna Concept



Ka-band T/R Module 8-pack

Round 1 ACT Microwave Projects

Gudim, Mimi, Jet Propulsion Laboratory

Synthetic Aperture (SAR) Radar On-board Azimuth Pre-Filter Processor

Objective

- Use high density FPGA technology to develop a prototype on-board azimuth pre-processing filter for synthetic aperture radar (SAR) systems, to reduce downlinked data volume by a factor of 4 or more (selectable factor)
- Tailor the architecture to allow incorporation of the processor into future SAR missions.

Kim, Edward, NASA GSFC

Controlled-Correlation Subsystem for On-board Receiver Calibration of Synthetic Thinned Array Radiometers (STAR) and Fully-Polarimetic (FP) Microwave Radiometers

Objective

- Develop a low-power subsystem for in-flight STAR/FP receiver calibration including a signal source with correlation properties, and a correlation receiver for realistic test conditions/optimization.
- STAR radiometers can provide high spatial resolution imaging without requiring a filled aperture or a moving antenna

Dual Channel Noise Source

Round 1 ACT Microwave Projects

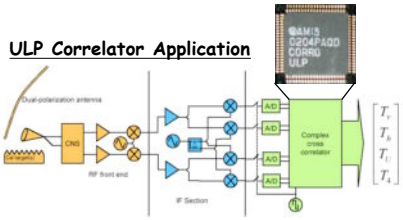
Piepmeier, Jeffrey, NASA GSFC

Ultra Low-Power Digital Correlator for Passive Microwave Polarimetry

Objective

- Develop and ultra-low-power, radiation-tolerant, CMOS, 500 MHz, 3-level, digital, complex cross-correlator for passive microwave polarimetry.
- Develop the correlator with a path to space flight use.

ULP Correlator Application



Doiron, Terrence, NASA GSFC

Development of a Low Power, Miniaturized Module for the Next Generation of Microwave Radiometers

Objective

- Design a receiver module with a power consumption of < 0.25W per frequency per polarization (approximately 1W per module) and a mass of approx. 0.2 kg.
- With a noise temperature of <250K it will directly address the implementation of many future hydrology missions.

Local Oscillator board

IF amplifier and filter

Round 2 IIP Microwave Projects

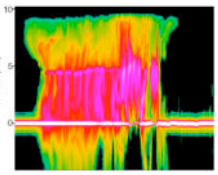
Im, Eastwood, Jet Propulsion Laboratory

Advanced Precipitation Radar Antenna and Instrument (APRA)

Objective

- Develop a half-size (2.6m x 2.6m) model of a lightweight, deployable, dual frequency, wide-angle beam-pointing antenna for spaceborne rainfall measurements.
- Incorporate the antenna's physical and performance characteristics into the overall system design of the Second-Generation Precipitation Radar (PR-2).

Airborne PR-2 simulator measured detailed rain structure of Tropical Storm Chantal during CAMEX-4



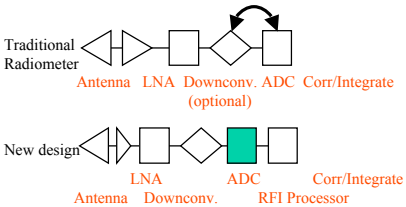
The structural model of APRA half-size antenna reflector prototype

Johnson, Joel, The Ohio State University

Digital Receiver With Interference Suppression for Microwave Radiometry

Objective

- Design and build a prototype L-band radiometer and demonstrate operation in the presence of interference.
- Demonstrate improved bandwidth which will enable improved accuracy and sensitivity of soil moisture and salinity measurements.



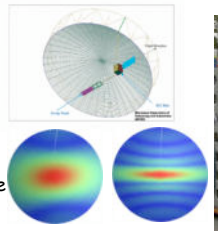
Round 2 IIP Microwave Projects

Moghaddam, Mahta, University of Michigan

Microwave Observatory of Subcanopy and Subsurfac (MOSS)

Objective

- Design, develop, and test a prototype UHF/VHF radar antenna feed system to enable 7-10 day observations of subcanopy & subsurface soil moisture at 1Km res. Long and thin apertures are synthesized using a dual-frequency feed subilluminating a 30-m parabolic mesh reflector.
- Generate validation science data set through ground experiments with a UHF/VHF tower radar.



Currents synthesized on reflector

Smith, Eric, NASA GSFC

Lightweight Rainfall Radiometer

Objective

- A new passive microwave radiometer instrument that uses advanced MMIC and digital correlator chip technology to measure precipitation (10.7 GHz)
- Synthetic-Thinned Array Radiometer (STAR) technology: lightweight, miniaturized, 50% less power, fixed-non deployable antenna for large apertures, and low recurring cost

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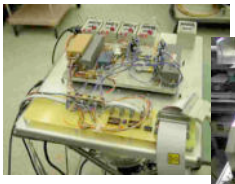
Round 2 IIP Microwave Projects

Wilson, Bill, Jet Propulsion Laboratory

Ultra Stable Microwave Radiometers for Future Sea Surface Salinity Missions

Objective

- Research and development for an advanced precision spaceborne radiometer to measure sea surface salinity (SSS).
- A measurement accuracy of 0.1 psu (practical salinity unit, or parts per thousand) requires a radiometer with high accuracy and a calibration stability of 0.05 K for 8 days.



JPL Testbed

GSFC Cryogenic Testbed

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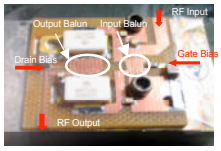
Round 2 ACT Microwave Projects

Edelstein, Wendy, Jet Propulsion Laboratory

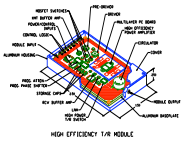
Ultra-High Efficiency L-band T/R Modules for Large Aperture Scanning Antennas

Objective

- Develop a lightweight, high-power, high-efficiency L-band T/R module for use in SAR antennas.
- The T/R module performance goal is to achieve an overall module efficiency of 70% with a minimum of 30-Watts output power at L-band frequencies.



900 MHz Class-E/F PA, 30W, 64% eff, 12 dB gain



Layout of integrated L-band T/R module

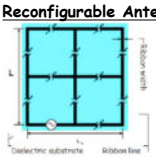
Knowles, Gareth, Qortek

Multiband Reconfigurable Synthetic Aperture Radar

Objective

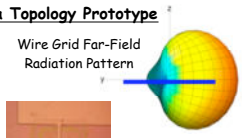
- Investigate the combining of advanced antenna engineering concepts with Frequency Selective Surfaces (FSS) implemented by Active Tuned Dielectric Materials (ATDM) and tuning achieved using Thin Film Transistors (TFT).
- Provide thin, lightweight reconfigurable conformal multiband arrays for space-based SAR systems

Reconfigurable Antenna Topology Prototype



'Inductor-less' Ribbon Grid Antenna Pixel with tunable elements

Wire Grid Far-Field Radiation Pattern



Integrated Pixel Select TFTs

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Round 2 ACT Microwave Projects

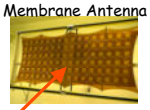
Moussessian, Alina, Jet Propulsion Laboratory

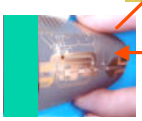
T/R Membranes for Large Aperture Scanning Antennas

Objective

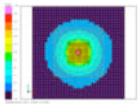
- Design, construct, and test Transmit/Receive (T/R) modules compatible with very large flexible membrane phased arrays.
- Flexible thin-film membrane antennas have the potential to replace rigid manifold antenna architectures and reduce the weight, volume and associated cost of space-based radars.

Membrane Antenna





Flex-Compatible T/R



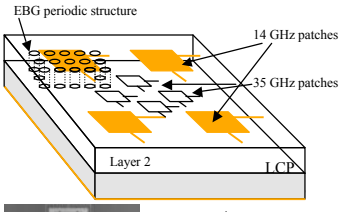
Temperature Profile

Papapolymerou, John, Georgia Tech

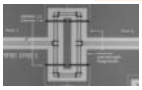
Lightweight, Deployable, Dual-Frequency/Polarization Microstrip Antenna Array for Remote Sensing of Precipitation

Objective

- Develop and demonstrate concepts and techniques that enable lightweight, deployable and low cost antenna arrays for remote sensing.
- Develop and demonstrate a 2x2 dual frequency/polarization microstrip array system on-a-package (SOP) including RF MEMS switches and phase shifters



Antenna array



RF MEMS phase shifter

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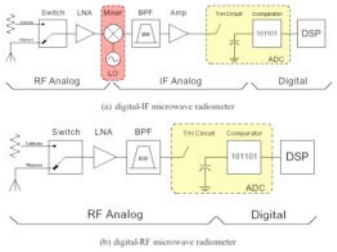
Round 2 ACT Microwave Projects

Piepmeier, Jeffrey, NASA GSFC

Low-Power Radio-Frequency Analog-To-Digital Converter (RF-ADC) for Digital Microwave Radiometry with Application to Soil Moisture Remote Sensing

Objective

- Develop a low-power (less 330 mW) RF-ADC for L-band digital microwave radiometers

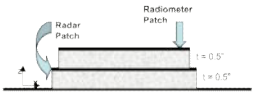


Yueh, Simon, Jet Propulsion Laboratory

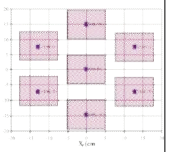
Compact, Lightweight Dual-Frequency Microstrip Antenna Feed for Future Soil Moisture and Sea Surface Salinity Missions

Objective

- Develop an innovative, compact, lightweight, dual-frequency antenna feed for future soil moisture and sea surface salinity (SSS) missions.
- Support future high-resolution soil moisture and SSS systems operating at low (L-band) microwave frequencies having large reflectors with multiple feeds.



Stacked radar and radiometer patches above a ground plane



Hexagonal array configuration of 7 stacked patches

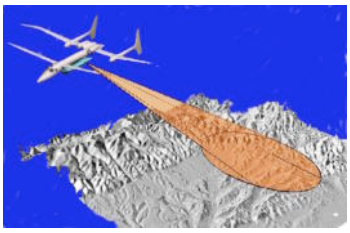
Round 3 IIP Microwave Projects

Hensley, Scott, Jet Propulsion Laboratory

Rapid-Repeat Deformation Measurement Capability for the NASA AIRSAR System

Objective

- Develop a repeat pass radar interferometry capability for measuring rapidly deforming surfaces on a UAV or Proteus aircraft.
- Develop a polarimetric, electronically scanned, L-band array and associated radar system that is an easily deployed instrument with radar steering that can be linked to on-board INU.

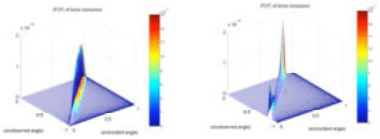


Hussein, Ziad, Jet Propulsion Laboratory

Cryospheric Advanced Sensor: A Spaceborne Microwave Sensor For Sea Ice Thickness and Snow Cover Characteristics

Objective

- Develop a combined spatial and frequency domain interferometer (SI/FDI) radar instrument for determining sea ice thickness and snow cover characteristics and do a field demonstration.
- Develop technology to support a future cryospheric spaceborne mission that will combine frequencies required for both sea ice thickness (VHF-band) and snow cover characteristics (Ku-band).



Left: Frequency and angular correlation of brine inclusion in the sea ice (137/ 118 MHz)
Right: Frequency and angular correlation of brine inclusion in the sea ice/ pronounce reduction of volume scattering (137/162MHz)

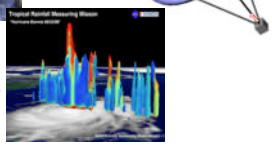
Round 3 IIP Microwave Projects

Im, Eastwood, Jet Propulsion Laboratory

NEXRAD-In-Space (NIS): A Radar for Monitoring Hurricanes from Geostationary Orbit

Objective

- Develop a system design for a Ka-band, Doppler radar in geostationary orbit for monitoring hurricanes and severe storms with a deployable, 28-m aperture, spherical antenna reflector and the 35-GHz spiral scan antenna feed set.
- Prototype a 1.5-m model of the NIS antenna reflector/ feed set to verify the pattern performance during scan.



NIS radar antenna concept and spiral scan ground coverage

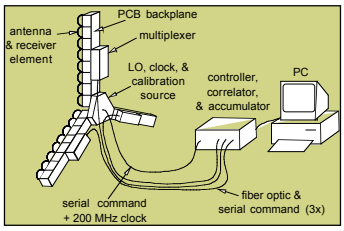
Hurricane cloud top imagery acquired by GOES, and vertical rain profiles acquired by TRMM radar.

Lambrigtsen, Bjorn, Jet Propulsion Laboratory

GeoSTAR: Geostationary Synthetic Thinned Aperture Radiometer

Objective

- Develop a prototype for GeoSTAR and use it to demonstrate the 2-D thinned array measurement concept and the required technology for mm-wave STAR instruments.
- Develop a roadmap to an operational flight GeoSTAR instrument on a NOAA GOES mission.



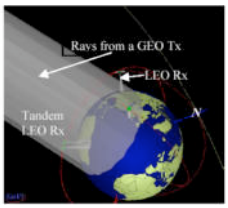
Round 3 IIP Microwave Projects

Sarabandi, Kamal, University of Michigan

Geostationary/Low-Earth Orbiting Radar Image Acquisition System (GLORIA): A Multi-Static GEO/LEO SAR Satellite Constellation for Earth Observation

Objective

- Provide a study for a new advanced concept in synthetic aperture radar remote sensing.
- Investigate comparative performance, phenomenological surface scattering, and system feasibility.



GLORIA's Conceptual Configuration of LEO and GEO Satellites.

Summary

- ESTO has invested in many microwave remote sensing systems through open, competitive, peer-reviewed solicitations.
- These investments in active and passive microwave and millimeter-wave measurement concepts are directly enabling and enhancing the many measurements required by the Earth science program at NASA.